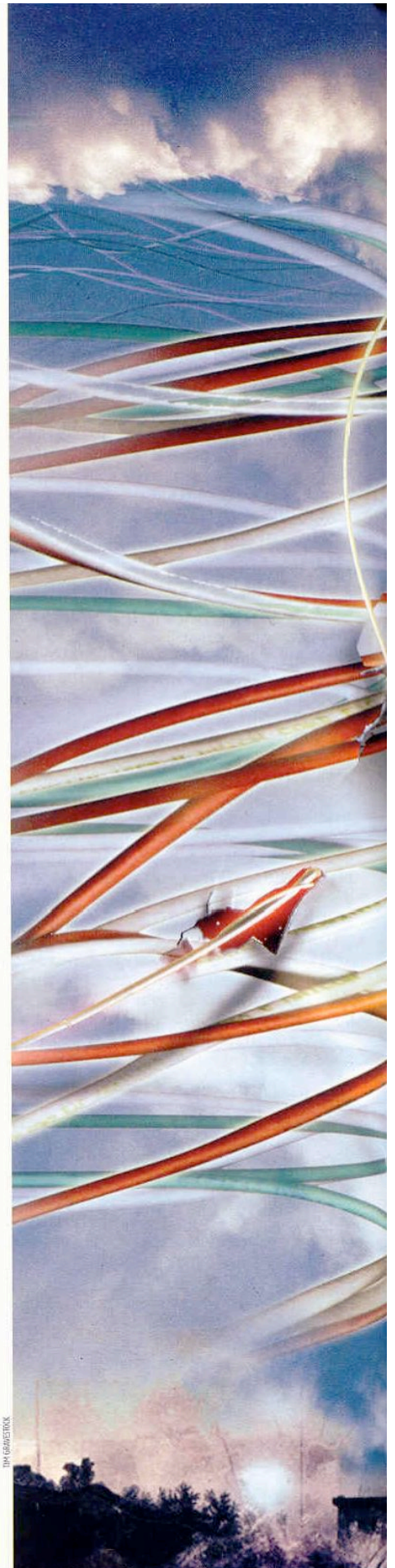


Cover feature |

IT CAME FROM **ANOTHER** DIMENSION

Astronomers think they have spotted a thread of pure energy streaking through our galaxy. Is this the first evidence for string theory, asks **Marcus Chown**





IF YOU consider them separately, these two observations are hardly going to set the scientific world on fire. But together they add up to a spectacular possibility. In a tiny region of sky, astronomers have seen a dozen galaxies that appear as a curious sequence of double images. They have also observed a quasar whose brightness oscillates in an unexpected way. What could cause these odd phenomena? The only explanation that covers both is pretty mind-bending: “superstrings” of pure energy that can stretch millions of light years across the universe. Is this the first experimental evidence for string theory?

The theory is our best hope of understanding how the universe works at its most fundamental level. It suggests that the basic constituents of matter are impossibly narrow threads of concentrated energy. The various different ways these superstrings can vibrate correspond to different fundamental particles, such as the up-quark and the muon-neutrino. The idea is well on the way to becoming a “theory of everything”, uniting the laws of physics to explain how all matter and energy behave.

Visible strings

One of the strangest features of string theory is that it requires many more dimensions than we can see: the only way the vibration modes of the superstrings can be sufficiently diverse to create all particles is if the superstrings vibrate in a space-time of 10 dimensions. Of course, we appear to live in a universe with only four dimensions – three of space and one of time – so string theorists have postulated that the extra dimensions are “rolled up” much smaller than the dimensions of an atom. However, until now no one had seen evidence to support string theory, and many scientists dismiss its ideas as untestable conjectures. But are they about to be proved wrong?

The answer lies with the big bang that kicked our universe into existence. String theory suggests that our universe may be a three-dimensional island or “brane” moving through 10-dimensional space, and that the big bang might have been caused by a collision between two such branes (*New Scientist*, 16 March 2002, p 26). This kind of collision would release a tremendous amount of

energy, which would create a plethora of different kinds of stringy object. One type is the fundamental superstrings. Another is strange objects called Dirichlet or "D" branes that exist within each brane and as connections between branes, but intersect with only one dimension of our universe. As a result, they look to us like one-dimensional superstrings.

But these are not necessarily the tiny strings we associate with fundamental particles: they can be of all sizes right up

images of the galaxy only a few arc-seconds apart in the sky (an arc-second is roughly the angle a small coin would make when seen from 2 kilometres away). And this is exactly what an Italian-Russian group claims to have found last year. The team, led by Mikhail Sazhin of Capodimonte Astronomical Observatory in Naples and the Sternberg Astronomical Institute in Moscow, christened the image pair Capodimonte-Sternberg Lens Candidate 1, or CSL-1. It consists of two apparently identical

University in Ohio is similarly optimistic. When he first noticed Sazhin's paper, he and his student Dragan Huterer tried to come up with reasons why a string could not be responsible. One of the first things that occurred to them was gravitational lensing, and they soon realised this hypothesis could easily be tested. The way galaxies are randomly distributed throughout the universe means that if you look at a patch of sky, gravitational lensing should be a rare phenomenon. If there's a string around, however, double images will be a lot more common. "A string should create other double images of galaxies in the neighbourhood – far more than would be expected by random chance," he says. "A simple follow-up observation should be enough to resolve the issue."

Sazhin and his colleagues have now made just such an observation. In a "field" 16 arc-minutes square centred on CSL-1, they found 11 other double images. Between nine and 200 would be expected for a string, they say, but just two would be expected by chance from the gravitational lensing of intervening galaxies. "This already sounds very exciting," Vachaspati says.

Good vibrations

It's particularly exciting because CSL-1 is not the only observational evidence for a string: there is also the curious case of the double quasar known as Q0957+561A,B, the first confirmed case of a gravitationally lensed object, observed by the Jodrell Bank telescope in the UK, in 1979. The two images are formed by the gravity of a galaxy that bends the light of the quasar so that it follows two distinct paths to Earth. The paths are different lengths and so the light takes a different time to travel along each one. As a result, outbursts in one image are mimicked by identical outbursts in the other image 417 days later.

This year, a team from the US and Ukraine, led by Rudolph Schild of the Harvard-Smithsonian Center for Astrophysics, noticed some peculiar anomalies. Four times between September 1994 and July 1995, the two images of Q0957+561A,B brightened and faded by about 4 per cent, but without any time delay. Each oscillation in brightness lasted about 100 days, and they were not repeated.

The only way such a synchronous change in brightness could occur would be if the cause was not the quasar itself but rather an object between the quasar and the Earth. Schild and his colleagues claim that the idea that best fits the bill is an oscillating loop of string. These oscillations would occasionally cause the string to encroach on the two light paths from the quasar, altering the images we see. The string also appears to be moving across our line of sight at about 70 per cent of the speed of light – which is why

"Superstrings are well on the way to becoming a 'theory of everything', uniting the laws of physics to explain how all matter and energy behave"

to astronomical dimensions. "Contrary to what we used to think, fundamental strings need not be ultra-tiny," says Tom Kibble of Imperial College London. And the bigger strings can be big enough to leave a visible mark on our universe. That's because a string distorts the space around it in a unique way. We are used to objects with mass or energy distorting the space around them, rather like a person's weight distorting the flat surface of a trampoline. This distortion of space is the origin of every object's gravitational attraction. However, a string is somewhat different from a normal object. All its energy is held on a one-dimensional line, not spread through space, and this concentrated energy distorts the space around it into a conical shape, with the string as its axis.

If there were a string between us and a distant galaxy, it would distort the light of the galaxy so that it could take two possible routes to the Earth. The result would be two identical

elliptical galaxies roughly 10 billion light years from Earth and a mere 2 arc-seconds apart (*Monthly Notices of the Royal Astronomical Society*, vol 343, p 353).

Seeing two identical galaxies is nothing new: it also arises from a phenomenon known as gravitational lensing (*New Scientist*, 13 November, p 42). This occurs when light from a distant galaxy passes close to another galaxy on its way to Earth. The mass of the intervening galaxy distorts the path of the light, producing multiple images of the distant galaxy. But gravitational lensing tends to manifest itself as an odd number of images that differ in brightness, often greatly. In the case of CSL-1, no intervening galaxy or cluster of galaxies is visible, there are just two images, and they are of equal brightness. So gravitational lensing doesn't seem to offer an explanation. "It looks like the signature of a string to me," says Kibble.

Tanmay Vachaspati of Case Western Reserve

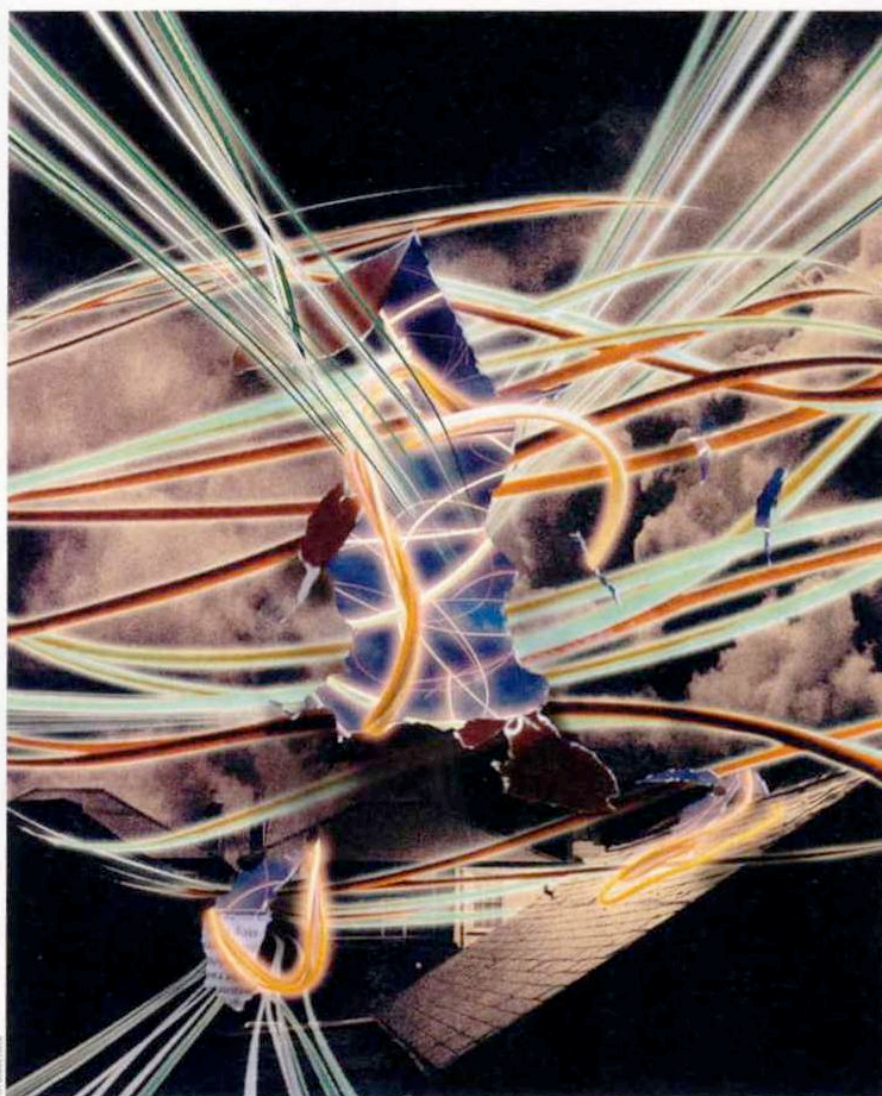
Return of the cosmic string

WE ALREADY know there cannot be an enormous number of giant superstrings out there. That's because they share many characteristics with "cosmic strings", concentrated threads of energy that physicists once believed to be scattered throughout space. In the 1980s, cosmologists were greatly interested in such structures: they were thought to be defects in space and time, formed by abrupt misalignments in the fundamental fields of nature when the universe cooled in the aftermath of the big bang, and locked forever in the weave of the fundamental fields threading the universe.

Cosmic strings would be massive, and according to theory their gravity was of exactly the right strength to drag in the cooling debris of the big bang and seed the great superclusters of galaxies we see in today's universe.

The observations, unfortunately, did not play ball. The gravity of cosmic strings should distort the cosmic background radiation – the "afterglow" of the big bang fireball – in a particular way, creating distinctive features. These were not seen. More seriously, experiments such as Boomerang and NASA's Wilkinson Microwave Anisotropy Probe, which each made detailed measurements of the

radiation's temperature differences across different angular scales, saw sharp fluctuations in the temperature of the background radiation. The existence of such sharp peaks was seen as a natural consequence of the fact that the universe had a very particular size, or scale, at the end of an early epoch of super-fast "inflation". If cosmic strings – or the superstrings created by brane collisions in string theory – had indeed seeded structures in today's universe, no such sharply peaked features would be created. That's because, according to the theoretical ideas behind them, both types of strings are created with all possible sizes.



unique string aspects are confirmed, I think we should remain a little cautious."

It is always possible, for example, that the fluctuations in the brightness of Q0957+561A,B looked the same entirely by chance. Abraham Loeb of the Harvard-Smithsonian Center for Astrophysics still favours the possibility that we have just seen a set of identical twin galaxies. "CSL-1 is most likely just a pair of galaxies that happened to be close together on the sky," he says. "We know of many close pairs of galaxies in the local universe, including our own Milky Way and Andromeda."

Such a coincidence would be disappointing, Vachaspati says. "I am hoping nature won't have played such a trick on us." What everyone needs now is more evidence. To prove that each galaxy pair is a lensed, double image of a single galaxy, it will be necessary to measure the spectra of both objects and show them to be the same. Another angle of attack would be to find more candidates like CSL-1 and Q0957+561A,B. But the best approach might be to look for gravitational waves.

Strings would produce gravitational waves because they get kinked as they meet each other in space. As two straight strings cross, for example, they can emerge from the meeting as two V-shaped strings. Every time strings cross, they can become more kinked, and to shake off a kink they emit a shockwave, cracking like a whip. This shockwave travels at almost the speed of light, and should produce an intense burst of gravitational waves. As first pointed out by Thibault Damour of the Institut des Hautes Études Scientifiques in Paris and Alex Vilenkin of Tufts University in Massachusetts, "cusp" signals could be spotted by the VIRGO or LIGO gravitational wave detectors. "The signals are very distinctive," says Joe Polchinski of the University of California at Santa Barbara. "If they exist, they could be picked up in the next few years."

According to Polchinski, if strings are discovered it will take at least a decade to measure the signals precisely enough to deduce their properties. This, he says, may enable us to pin down their origins. It could be another source of disappointment: the observed strings could have nothing to do with string theory, but be low-energy versions of the cosmic strings that were once thought to have seeded the universe's structure (see "Return of the cosmic string", left).

Nevertheless, it's an exciting prospect. String theory is big on imagination-stirring concepts, such as vibrating threads of energy that inhabit a multidimensional reality, and awesome collisions that create new universes. It may be that these elusive and fantastical strings have finally shown themselves. ●

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"We are left with the conclusion that we are very lucky to have a string on our doorstep"

it affected the quasar for only a limited time.

To oscillate once every 100 days or so, the loop has to be very small in astronomical terms – roughly 10¹¹ kilometres. It also has to subtend an angle at the Earth substantially smaller than the separation of the images or it would create a spiky variation in the quasar's brightness rather than the smooth, periodic variation observed. The combination of these two conditions implies that the string is shockingly close to us – in our own galaxy, within about 10,000 light years of the sun.

So is it pure coincidence that a stringy relic of the big bang has ended up in our neighbourhood, or are these things scattered liberally throughout the universe? Strings would also emit gravitational waves and these should distort the space between them and us,

introducing fluctuations in the time light takes to reach us and therefore in the observed timings of pulses. Though Kibble points out that there are a number of uncertainties in this calculation, the fact we do not see such an effect suggests a limit on how many strings there are between us and known pulsars. So we are left with the conclusion that we are very lucky to have a string on our doorstep.

Scientifically speaking, that's not a very satisfying conclusion. Indeed, the whole question of string observation is still riddled with uncertainty, and many researchers are wary of rushing to conclusions about Sazhin's observations. "I think it is too early to get excited," says Edmund Copeland of the University of Sussex in the UK. "There may be other possible explanations. Until the